1. DOE Award No. DE-SC0012704	2. Contractor No. 2017-BNL-PO001-Budg	3. Date Prepared: 07-26–2016	4. Task Term: Begin: Continuing End: Open

5. Title: Heavy Ion Research

6. Principal Investigator: Morrison, David, (631) 344-5840

9. Heavy-Ion Program Manager: James Sowinski (301) 903-7587 Office of Nuclear Physics DOE Office of Science US Department of Energy 19901 Germantown Road Germantown, MD 20874-1290	12. Headquarters Organization: Office of Science 13. Program Office: Germantown, MD 14. Contractor Name: BROOKHAVEN SCIENCE ASSOCIATES BROOKHAVEN NATIONAL LABORATORY	

18. Project Description:

The BNL PHENIX group has played an important role in the management and science mission of the PHENIX experiment and has supported 250 visiting collaborators each year. The PHENIX group primarily performed its current research at RHIC, with particular emphasis on photons, neutral hadrons, and bulk properties of the medium, for systems ranging from p+p to d+Au to Au+Au (and U+U). It plays a major role in the design and construction of the future sPHENIX experiment, which will study high pT processes (jets and photons) and heavy quarkonia over a wide kinematic range. Several members of the group also perform research with the ATLAS detector at the LHC, with focus on collective behavior and high pT probes (jets and photons) in both Pb+Pb and p+Pb collisions. Members of the group are also playing important roles planning for the future scientific programs at RHIC, including the beam energy scan, forward physics with p+p and p+A, and physics at the proposed electron-ion collider.

19. Principal Investigator:

07/26/2016

Signature(s)

Date: 07/28/16

Continuing Progress Report
BNL PHENIX Group 2016

The BNL/PHENIX Group provides substantial scientific leadership to the physics research effort of the PHENIX experiment, contributes essential support for the operation of the PHENIX experiment, plays a key role in the ATLAS Heavy Ion Program, carries out analysis of physics data on a variety of topics from both PHENIX and ATLAS, and is deeply involved in the plans for future upgrades of PHENIX leading to sPHENIX and a future detector for eRHIC. Many members of the group split their time between research and operations.

BNL/PHENIX group research leadership positions include:

PHENIX Co-spokesperson – D. Morrison (through December 2015),
Executive Council members – J. Huang, M. Chiu
PHENIX Physics Working Group and Topical Group conveners – T. Sakaguchi, G. David, M. Chiu
PHENIX Scientific Admin and Publications – B. Johnson

sPHENIX Co-spokesperson – D. Morrison (starting January 2016)
sPHENIX Project Coordinator – E. O'Brien
sPHENIX Project Manager- Science – J. Haggerty
sPHENIX Physics Working Group and Topical Group conveners – J. Huang, D. Perepelitsa

BNL/PHENIX group members also hold numerous positions in PHENIX that support the scientific research program including Operations Director (Chiu), Deputy Operations Manager (Haggerty), Data Production Manager (Franz), DAQ Coordinator (Purschke), Computing Coordinator (Pinkenburg), and five seats on the Detector Council (including the chair). Nouicer also manages daily operation and maintenance of the PHENIX VTX stripixel subsystem.

We would like to point out the special role of Brant Johnson in the PHENIX research effort. He provides crucial support of PHENIX operations and datataking, but also the research effort, including the analysis and public release of physics results. In the last year, he continued his service as PHENIX Office Manager and Secretary of the PHENIX Institutional Board (IB) and Executive Council (EC). He participated in the preparation and revision of all PHENIX physics papers and submitted and resubmitted them to the physics journals Phys. Rev. Letters, Phys. Rev. C, Phys. Rev. D, and Science . He organized the monthly PHENIX Core Weeks and coorganized Collaboration meetings. Finally, he maintained the PHENIX mailing, current participants, and qualified author lists. We are sorry to see him leave our group this year.

PHENIX Research progress in 2015-16

The BNL physics PHENIX group contributed to 20 papers in FY2015 and FY2016 (as primary authors or review committee members):

1. "Measurement of Upsilon production in p+p and Au+Au collisions at sqrt(s) = 200 GeV" (Phys. Rev. C 91, 024913, 2015) (**Purschke** served as review chair)
2. "Systematic Study of azimuthal anisotropy in Cu + Cu and Au + Au Collisions at sqrt(s_NN) = 62.4 – 200 GeV" (Phys. Rev. C 92, 034913, 2015) (**Nouicer** served on analysis team)

3. "Measurement of long-range angular correlation and quadrupole anisotropy of pions and (anti)protons in central d+Au collisions at sqrt(s_NN)=200 GeV" (Phys. Rev. Lett 114, 192301, 2015) (**Sickles** on analysis team before she left BNL)
4. "Centrality dependence of low-momentum direct-photon production Au+Au collisions at sqrt(s_NN) = 200 GeV" (Phys. Rev. C 91, 064904, 2015) (**David** on analysis team)
5. "Nuclear matter effects on J/psi production in asymmetric Cu+Au collisions at sqrt(sNN) = 200GeV" (Phys. Rev. C 90, 064908, 2014) (**Franz** on review committee)
6. "Search for dark photons from neutral meson decays in p+p and d+Au collisions at sqrt(s) = 200 GeV" (Phys. Rev. C 91, 031901, 2015) (**Morrison** on analysis team, **O'Brien** on review committee)
7. "Beam energy and system-size dependence of the space-time extent of the pion emission source produced in heavy ion collisions" (submitted to PRL) (**Mitchell** on analysis team, **Tannenbaum** on review committee)
8. "Measurement of parity violating spin asymmetries in $W^{\pm}$ production at mid-rapidity in longitudinally polarized p+p collisions at sqrt{s}=510 GeV" (Phys. Rev. D 93, 051103, 2016) (**Huang**, review committee chair)
9. "Cross section and transverse single spin asymmetry of eta mesons in p+p collisions at sqrt(s) = 200 GeV at forward rapidity" (Phys. Rev. D 90, 072008, 2014) (**Chiu** on analysis team)
10. "Measurement of higher cumulants of net-charge multiplicity distributions in Au+Au collisions at sqrt(s_{NN}) = 7.7 to 200 GeV" (Phys. Rev. C 93, 011901, 2016) (**Mitchell** and **Tannenbaum**, analysis team)
11. "Measurements of elliptic and triangular flow in high multiplicity 3He+Au collisions at sqrt(s_NN) = 200 GeV" (Phys. Rev. Lett. 115 142301, 2015) (**Huang** on review committee)
12. "Centrality-Dependent Modification of Jet-Production Rates in Deuteron-Gold Collisions at sqrt(s_NN) = 200 GeV", arXiv:1509.04657 (Phys. Rev. Lett. 116, 122301, 2016) (**Perepelitsa**, lead analyzer)
13. "Measurements of directed, elliptic and triangular flow in Cu+Au collisions", arXiv:1509.07784 (submitted to PRC) (**Franz** on review committee)
14. "Single electron yields from semi-leptonic charm and bottom decays in Au+Au collisions at √sNN = 200 GeV" (Phys. Rev. C 93, 034904, 2016) (**Nouicer** was on analysis team)
15. "Scaling properties of fractional momentum loss of high pT hadrons in relativistic heavy ion collisions", (Phys. Rev. C 93, 024911, 2016) (**Sakaguchi** and **Tannenbaum**, lead analyzers)
16. "Azimuthally anisotropic emission of low-momentum direct photons in Au+Au collisions at sqrt(s_NN)=200 GeV", arXiv:1509.07758 (submitted to PRC) (**David** supervised analysis and co-wrote paper).
17. "Dielectron production in Au+Au collisions at √sNN = 200 GeV", (Phys. Rev. C 93, 014904, 2016) (**Sakaguchi** on analysis team)
18. "Inclusive cross section and double helicity asymmetry for \pi^0 production in p+p collisions at sqrt{s}= 510 GeV" (Phys Rev D. 93 011501, 2016) (**Huang** on review committee)
19. "Transverse energy production and charged-particle multiplicity at mid-rapidity in various systems from sqrt(s_NN)=7.7 to 200 GeV" (Phys. Rev. C 93 024901, 2016) (**Mitchell** and **Tannenbaum** on analysis team)
20. "Phi meson production in the forward/backward rapidity region in Cu+Au collisions at sqrt(s_NN)=200 GeV" (Phys. Rev. C 93 024904, 2016) (**Purschke** was review committee chair)

The group played a major role preparing for the future physics program at BNL:

- The Hot QCD White Paper: Exploring the Phases of QCD at RHIC and the LHC. 2015, arXiv:1502.02730 [nucl-ex]. This document provided community input to the NSAC long-range planning process. (D. Morrison co-author)

- The sPHENIX proposal, updated in November 2014. The work going into this document was key to the success of the sPHENIX science review in April 2015.

The group played a central role in the successful DOE review on the sPHENIX science case in April 2015.

The group also participated in the sPHENIX cost and schedule review in November 2015. According to ALD Mueller (Dec 2015 newsletter), "The committee found the technical design to be well advanced and reasonably mature for a project at the pre-CD0 stage and that the presented cost and schedule estimates were credible, but recommended an increase in the contingency. The committee recommended that a postponement of first data taking by one year, to 2022, should be considered to allow for a less aggressive construction schedule. Overall, the review was positive and helped to identify the remaining challenges on the path to an official approval of the sPHENIX project."

The group led a successful test beam effort at FNAL in early 2015 to evaluate initial prototypes of the sPHENIX EMCal and HCal. This is being followed up in FY2016 with a beam tests at FNAL of second generation calorimeter prototypes. Specific contributions were made by Chiu, Woody, Purschke

Contributions from the BNL/PHENIX group were critical to PHENIX during Run-15 in which were recorded 110 pb^{-1} of polarized pp data at 200 GeV, 403 nb^{-1} of polarized p+Au collisions at 200 GeV. RHIC also delivered p+Al collisions during Run 15. A beam loss event in the accelerator damaged the PHENIX MPC readout, which compromised one particular aspect of the PHENIX run plan. The MPC readout was subsequently reengineered using newly available components in order to be resilient against any future such beam loss event. Run 16 has been completed, collecting full energy Au+Au collisions, to be followed by 200 GeV d+Au energy scan. The final event counts were 1) 23.4 billion Au+Au events at 200 GeV, 2) 2.2 billion d+Au events at 200 GeV, 3) 1.83 billion d+Au events at 62 GeV, 4) 2.9 billion d+Au events at 39 GeV, and 5) 1.4 billion d+Au events at 19.6 GeV.

US ATLAS HI

The BNL involvement in the ATLAS heavy ion program at the LHC has been matrixed into the STAR and PHENIX groups via the involvement of Steinberg and Perepelitsa in PHENIX, and Jia and Debbe in STAR. The BNL group overall made important physics contributions in the last year to the ATLAS physics effort, including the resumed data-taking with colliding lead beams at the end of 2015.

In FY15, members of the group made major contributions to the ATLAS heavy ion program:

- Jia continued in his second year as ATLAS Heavy Ion Physics group co-convenor (Steinberg will replace him in October 2016)
- Steinberg continued on as subconvenor of the HI electroweak/quarkonia working group
- Steinberg was appointed project leader of the ATLAS Zero Degree Calorimeter, and led a test beam campaign in May 2015 at the CERN SPS.
- Steinberg and Perepelitsa remained in charge of the Run2 Pb+Pb centrality calibration.
- Steinberg and Debbe contributed to the ultra peripheral collision (UPC) trigger design in advance of the November run.

Submitted papers (and associated conference notes) with BNL group involvement are

- Measurement of the dependence of transverse energy production at large pseudorapidity on the hard-scattering kinematics of proton--proton collisions at $\sqrt{s}$=2.76 TeV with ATLAS (published in Phys. Lett. B)
- Measurement of the centrality dependence of the charged particle pseudorapidity distribution in proton-lead collisions at $\sqrt{s_{NN}}$=5.02 TeV with the ATLAS detector (published in EPJ C)
- Centrality, rapidity and transverse momentum dependence of isolated prompt photon production in lead-lead collisions at $\sqrt{s_{NN}}$=2.76 TeV measured with the ATLAS detector (published in Phys. Rev. C)
- Measurement of high-mass exclusive dimuons in ultra-peripheral collisions (conference note only)

The group will continue to work on analysis of proton-proton, proton-lead and lead-lead data. Particular focus is on photons and photon+jet correlations, collective behavior, and ultra peripheral collisions (motivated by the group's increased involvement in the ATLAS ZDC)

Expected progress in 2016-2017

The BNL/PHENIX Group will continue to have a leading role in the physics research effort of the PHENIX experiment, provide essential support for the operation of the PHENIX experiment, play a key role in the ATLAS Heavy Ion Program, carry out analyses of PHENIX and ATLAS data physics data and be deeply involved in the development of sPHENIX.

- Analysis of d+Au data taken with the MPC-EX detector in Run 16.
- Study of long range correlations in small systems (p+p and d+Au)
- Study of jet production in Cu+Au collisions
- Continued analysis of the 510 GeV polarized p+p data
- Continued analysis of the flavor-separated heavy flavor data from the VTX and FVTX

Several topics will receive less attention than in previous years, due to the RIFs experienced by the PHENIX group in FY16

- Continued analysis of data from the RHIC Beam Energy Scan.
- Continued analysis and publication of results on high pT photons and neutral hadrons, both their yields and azimuthal asymmetries

As of Run 17, components of the PHENIX detector will have begun to be removed and repurposed in advance of the sPHENIX upgrade. The transition of the group to fully support sPHENIX will continue. Members of the group will develop new prototypes of the calorimeters and be involved in the physics working groups of sPHENIX as it refines its physics program.

The ATLAS HI effort will contribute to further commissioning and data taking in Run 2 (8 TeV p+Pb data expected in November 2016), and to jet, photon and UPC measurements with Run 2 data.

The next sections outline group work outside the main experimental efforts: EIC R&D, organizational service work, service on review committees, and finally individual research efforts:

EIC-related R&D:

Huang contributed to EIC R&D projects on particle identification (eRD14) and calorimetry (eRD1).

Franz, Purschke and Woody made contributions to a paper "A study of a mini-drift GEM tracking detector" (IEEE Trans. Nucl. Sci. Vol. 63, No. 3 (2016) pp 1768-1776, http://arxiv.org/abs/1510.01747).

Purschke set up readout systems for a variety of outside groups involved in EIC R&D.

Organizational work from group members:

David and Tannenbaum organized the workshop on "High pT physics in the RHIC/LHC era", held at BNL in April 2016.

Purschke served as chair of the IEEE "Computer Application in Nuclear and Plasma Sciences" for the 3rd year. This group organizes the "Real Time" conference, which took place in June 2016. Martin served as chair of the executive board and handled much of the preparation for the conference.

Steinberg served on the International Organizing Committee for Initial Stages 2016, held in May 2016 year in Lisbon, Portugal.

External reviewer work from group members:

O'Brien served on a range of review committees in the last year: for the JLab 12 GeV Upgrade, an NSERC review of ATLAS-Canada, and a SECAR review of FRIB.

Purschke served on a review committee at JLab to address their readiness for the 12 GeV upgrade.

Tannenbaum reviewed a research proposal from Hungary OTKA, NKFI. He also reviewed two DOE NP proposals.

Individual research efforts:

This section lists work that group members perform that falls outside the main experimental efforts (PHENIX, sPHENIX, ATLAS HI).

David has been preparing for publication a recently-discovered 1909 autograph by Roland Eotvos, on the proportionality of gravitational and inertial mass. This was listed as a part of the World Memory by UNESCO in 2015. He gave two courses and a seminar at Debrecen University.

Franz' position in the PHENIX group ended this year, with the Reductions in Force of BNL Nuclear Physics. He has been re-hired to work on safety issues and serve as special assistant for Nuclear and Particle Physics Associate Lab Director Berndt Mueller.

Huang contributed to a perturbative QCD theory paper: "Consequences of high-x proton size fluctuations in small collision systems at RHIC" with collaborators from Los Alamos. He also maintains his participation on the development of the SoLID experiment at JLab.

Mitchell, Perepepelitsa and Tannenbaum contributed to a few-author paper (with Paul Stankus, co-author) on "Tests of constituent-quark generation methods which maintain both the nucleon center of mass and the desired radial distribution in Monte Carlo Glauber models" (Phys. Rev. C93 (2016) 054910) to address a shortcoming in Glauber calculations performed in a recent PHENIX paper.

Nouicer has been working on R&D for the sPHENIX silicon subsystems, and is in charge of building prototypes of the modules and ladder.

Nouicer served as an internal reviewer on a PHOBOS paper that was recently submitted and accepted by PRC "Studies of Nucleon-Gold Collisions at 200 A.GeV Using Tagged d + Au Interactions in PHOBOS" (Phys. Rev. C 98 (2015) 034915)

Nouicer wrote a review article "New State of the Nuclear Matter: 'Nearly Perfect Fluid of Quarks and Gluons' in Heavy Ion Collisions at RHIC Energies" (Eur.Phys.J.Plus 131 (2016) no.3, 70, http://arxiv.org/abs/1512.08993)

Perepelitsa contributed to several few author papers related to proton size fluctuations with several groups of collaborators: "Evidence for x-dependent proton color fluctuations in pA collisions at the CERN Large Hadron Collider", Phys. Rev. C93 (2016) 011902 (with Alvioli, Cole, Frankfurt and Strikman) and "Consequences of high-x proton size fluctuations in small collision systems at RHIC", with PHENIX collaborators Nagle and McGlinchey (submitted to Phys. Rev. C).

Pinkenburg was featured in the BNL news about his involvement coaching the "GearHeadz" youth robotics team (https://www.bnl.gov/newsroom/news.php?a=26484&btw=1), which led to him being named a 2015 Times Beacon Record Newspapers Person of the Year.

Purschke was a lecturer and instructor for a CERN school on trigger and data acquisition in Israel.

Steinberg serves on the BNL Council, and was appointed to the BNL Lectureship committee, which selects speakers for BNL distinguished lectures.

Woody was awarded an LDRD for "Investigation of the performance characteristics of Silicon Photomultiplier photosensors under extreme conditions for use in Nuclear and Particle Physics detectors" with members of BNL instrumentation.

Woody serves on the IEEE Nuclear and Plasma Sciences Awards Committee, which reviews and decides all NPSS awards.

Table I: group member information on 1) number of seminars and talks given, the number of review panels served-upon, and the the number of international and local conference committees served-upon in the last year.

Name	Seminar/talks	Review panels	IAC/LOC
Mickey Chiu			
Gabor David	1		0/1
Achim Franz	0		
John Haggerty	1		
Jin Huang	6		
Brant Johnson			
Edouard Kistenev	3		
Jeffrey Mitchell	1		1/0
David Morrison	4		0/1
Rachid Nouicer	6		
Edward O'Brien		3	
Dennis Perepelitsa	9		
Chris Pinkenburg			
Martin Purschke	7		1/1
Takao Sakaguchi	4		1/1
Peter Steinberg	4		1/0
Michael Tannenbaum	3		0/1
Craig Woody	4		1/3

FY2015 U.S. Department of Energy

Budget Page

ORGANIZATION		Budget Page No.: 1
Brookhaven National Laboratory	**KB0201021 Research - Phenix**	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR		Requested Duration: 12 (months)
David Morrison		

A. SENIOR PERSONNEL: PI/PD, Co-Pis, Faculty and Other Senior Associates (List each separately with title; A.6. Show number in brackets)		DOE Funded Person-mos.			
1 John Haggerty	Physicist	6.2			
2 Edward O'Brien	Physicist	7.4			
3 Michael Tannenbaum	Physicist	12.0			
4 Craig Woody	Physicist	8.9			
5 Brant Johnson	Physicist	1.9			
6 Edouard Kistenev	Physicist	7.8			
7 David Morrison	Physicist	8.2			
8 Martin Purschke	Physicist	4.9			
9 Peter Steinberg	Physicist	11.6			
10 Mickey Chiu	Physicist	6.1			
11 Gabor David	Physicist	9.0			
12 Achim Franz	Physicist	3.0			
13 Jeffery Mitchell	Physicist	8.9			
14 Rachid Nouicer	Physicist	6.2			
15 Christopher Pinkenburg	Physicist	4.9			
16 Takao Sakaguchi	Physicist	4.7			
17 Jin Huang	Asst Physicist	11.3			
Others (List individually on Budget Explanation Page)					
17	Total Senior Personnel	123.1	0.0	0.0	$2,099,388
B. OTHER PERSONNEL (show numbers in brackets)		M.m(months)			
1. 1	Post Doctoral Associates	4.0			$34,195
2. 2	Other Professional	9.0			$91,915
3.	Graduate Students				
4. ( )	Undergraduate Students				
5. 2	Secretarial - Clerical	10.2			$68,310
6.	Others (List individually on Budget Explanation Page) (joint appointment)				
Total Salaries and Wages (A + B)					$2,293,808
C. Fringe Benefits (if charged as Direct Costs)	Included in salary band rate				$0
Total Salaries,Wages and Fringe Benefits (A + B + C)					$2,293,808
D.					
Total Permanent Equipment					
E. Travel	1. Domestic (incl. Canada and U.S. Possessions)				$53,026
	2. Foreign				$27,068
Total Travel					$80,094
F. Trainee/Participant Costs					
	1. Stipends (Itemize levels, types and totals on budget justification page)				
	2. Tuition & Fees				
	3. Trainee Travel				
	4. Other (fully explain on justification page)				
Total Participants	Total Cost				$0
G. Other Direct Costs					
1. Materials and Supplies					$30,610
2. Publication Costs/Documentation/Dissemination					
3. Consultant Services					
4. Computer (ADPE) Services					
5. Subcontracts					$648
6. Other Organizational Burden, Space, electric, communications, other)					$603,659
Total Other Direct Costs					$634,918
H. **Total Direct Costs (A through G)**					$3,008,820
I. Indirect Costs (specify rate and base)					
Total Indirect Costs					$1,289,690
J. **Total Direct and Indirect Costs (H + I)**					$4,298,510
K. Amount of any Required cost sharing from Non-federal Sources					
L. **Total Cost of Project (J + K)**					$4,298,510

FY2016 U.S. Department of Energy

Budget Page

ORGANIZATION		Budget Page No.: 1
Brookhaven National Laboratory	**KB0201021 - Research PHENIX**	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR		Requested Duration: 12 (months)
David Morrison		

A. SENIOR PERSONNEL: PI/PD, Co-Pis, Faculty and Other Senior Associates (List each separately with title; A.6. Show number in brackets)		DOE Funded Person-mos.			
1 John Haggerty	Physicist	3.0			
2 Edward Obrien	Physicist	0.6			
3 Michael Tannenbaum	Physicist	6.6			
4 Craig Woody	Physicist	4.8			
5 Brant Johnson	Physicist	0.5			
6 Edouard Kistenev	Physicist	2.5			
7 David Morrison	Physicist	7.2			
8 Martin Purschke	Physicist	3.0			
9 Peter Steinberg	Physicist	12.0			
10 Mickey Chiu	Physicist	6.0			
11 Gabor David	Physicist	3.5			
12 Achim Franz	Physicist	1.7			
13 Jeffery Mitchell	Physicist	0.1			
14 Rachid Nouicer	Physicist	3.0			
15 Christopher Pinkenburg	Physicist	3.0			
16 Takao Sakaguchi	Physicist	3.5			
17 Jin Huang	Asst Physicist	10.8			
Others (List individually on Budget Explanation Page)					
17	Total Senior Personnel	71.7	0.0	0.0	$1,259,107
B. OTHER PERSONNEL (show numbers in brackets)		M.m(months)			
1. 1	Post Doctoral Associates	4.7			$43,367
2. 2	Other Professional	6.0			$70,779
3.	Graduate Students				
4. ( )	Undergraduate Students				
5. 2	Secretarial - Clerical	7.0			$49,618
6.	Others (List individually on Budget Explanation Page) (joint appointment)				
Total Salaries and Wages (A + B)					$1,422,871
C. Fringe Benefits (if charged as Direct Costs)	Included in salary band rate				$0
Total Salaries,Wages and Fringe Benefits (A + B + C)					$1,422,871
D.					
Total Permanent Equipment					
E. Travel	1. Domestic (incl. Canada and U.S. Possessions)				$39,259
	2. Foreign				$39,405
Total Travel					$78,664
F. Trainee/Participant Costs					
	1. Stipends (Itemize levels, types and totals on budget justification page)				
	2. Tuition & Fees				
	3. Trainee Travel				
	4. Other (fully explain on justification page)				
Total Participants	Total Cost				$0
G. Other Direct Costs					
1. Materials and Supplies					$62,546
2. Publication Costs/Documentation/Dissemination					
3. Consultant Services					
4. Computer (ADPE) Services					
5. Subcontracts					$0
6. Other	Organizational Burden, Space, electric, communications, other)				$748,461
Total Other Direct Costs					$811,007
H. **Total Direct Costs (A through G)**					$2,312,543
I. Indirect Costs (specify rate and base)					
Total Indirect Costs					$802,470
J. **Total Direct and Indirect Costs (H + I)**					$3,115,013
K. Amount of any Required cost sharing from Non-federal Sources					
L. **Total Cost of Project (J + K)**					$3,115,013

Budget Explanation

A. Senior Personnel Man/Montl Cost

Staff Listing is shown on the Budget Sheet.

B. Other Personnel

C. Fringe and labor burden which are included in the salary band rate

All fringe costs are included in the standard labor rates included in A and B sections. Salary cost data includes salary, paid absence, overtime shift and fringe benefit costs.

D. Capital Equipment

E. Travel

Includes attendance at conferences and visitors to BNL workshops

F. Trainee/Participant Costs

G. Other Direct Costs

Includes: Space, Physics Department Organizational burdens, On-site Housing and Miscellaneous Expenses

	FY 15 %	**FY 16** %	
Organizational Burden	14.5	14.7	applied to salary with fringe
Electric Distributed	1.18	1.18	applied to salary with fringe

I. Indirect Costs

	FY 15 %	**FY 16** %	
BNL Material Burden	7.50	7.50	applied to travel, purchases and subcontracts
BNL Common G&A	31.95	32.35	applied to , direct salary plus fringe, organizational burden, purchased goods, material burden, & allocated services
BNL Traditional G&A	8.25	8.25	applied to , direct salary plus fringe, organizational burden, purchased goods, and material burden
BNL LDRD Burden	3.70	2.30	In FY15 = applied to , direct salary plus fringe, organizational burden, purchased goods, material burden, & allocated services In FY16 = base is applied to Total Cost less housing
Composite rate	43.9	43.8	